Volume 19 December, 1933 *Number 12*

Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Distillery Operations

Emulsification, Demulsibility and Methods of Test

PUBLISHED BY
THE TEXAS COMPANY
TEXACO PETROLEUM PRODUCTS

TEXACO LUBRICATION RECOMMENDATIONS FOR

DISTILLERY MACHINERY

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PUMPS

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According to Type and Design	TEXACO REGAL OILS

THE TEXAS COMPANY

Texaco Petroleum Products

135 East 42nd Street, New York, N. Y.

Offices in Principal Cities

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A Technical Publication Devoted to the Selection and Use of Lubricants

Published by
The Texas Company, 135 East 42nd Street, New York City
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Vol. XIX December, 1933 No. 12

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Distillery Operations

WITH repeal, activity is increasing in what, particularly from the engineering angle, might be referred to as the forgotten industry. The mechanics attendant to the production of alcohol and alcoholic beverages are but little known to the average consumer, although we are all familiar with the fact that with the exception of certain synthetic compounds the manufacture of products containing alcohol involves the process of fermentation or fermentation plus distillation.

Molasses is extensively used as the basic source of the alcohols which are so widely employed for industrial, medicinal, beverage and anti-freeze purposes today.

Grains comprise the major part of the raw materials which are used in the manufacture of whiskey. According to locality and type of liquor to be made, corn, barley, rye, wheat or oats are used. Alone or in varying proportions, these are ground and mixed with malt to prepare the mash which is commonly known as wort. This wort is then treated with acid and heated with steam under pressure to convert the starch content to sugar. Modern practice in distillery operation can be divided into three stages, according to the nature of the product and work to be done thereon, as follows:

Mashing
Fermentation, and
Distillation.

Mashing is distinctly applicable to the distillery wherein grains are being handled. It is not essential where molasses is being used. The fermentation and distillation stages, however, apply regardless of the raw material.

Handling of raw materials in the distillery prior to fermentation is a matter of pumping, where molasses is used, or conveying and pumping where grains go to make up the mash.

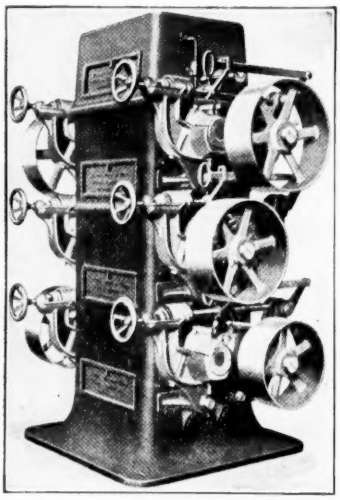
In the fermentation stage the sugar content of the mashed grain or diluted molasses is converted into alcohol and carbon dioxide. Fermentation is, therefore, a distinctly bacteriological reaction, accompanied by frothing or effervescence, as the carbon dioxide passes off. The resultant liquor is termed the wash.

The third stage, or the process of distillation is employed to separate the spirits from the secondary constituents, which go to make up the wash. By careful control of this process the flavor of certain of these constituents is retained to give distinction to the finished product, especially where it is manufactured from grains.

MANUFACTURE OF ALCOHOL

Where molasses is used, the residue after the alcohol is distilled off, is considered of no value; on the other hand the residue from grain distilleries is extensively used as cattle food, after suitable drying. Molasses is handled entirely by pumps, which constitute the greater part of the mechanical equipment in the molasses distillery. It is derived from sugar cane, and comes to the distillery in the form of a viscous brownish-colored fluid, which frequently requires heating to facilitate pumping.

In distillery operations the molasses is pumped from storage to the fermentation vats, and diluted with water to an average ratio of approximately one to six. As fermentation proceeds the carbon dioxide gas generated develops more or less foam on the



Courtesy of Allis-Chalmers Manufacturing Co.

Fig. 1—Showing a 3 high distillery mill of the roller type, as used for grinding grain.

surface of the vat contents, according to the source of the raw stock. Cuban molasses, for example, usually develops more foam than the product from the Porto Rican cane fields. To prevent excessive accumulation of this foam on the surface of the mash, various types of oil are sprayed or poured over the surface of the liquid. Sulfonated mineral oils are used in some plants, others use certain fixed or animal oils. This is interesting in contrast with brewery operations, where the utmost care must be taken, especially in the lubrication of machinery, in order to prevent entry of oil and reduction of the bead or foam-forming qualities.

As the process of fermentation approaches completion, the mash or vat contents give off less and less carbon dioxide, consequently activity and temperature generation are reduced. Finally the product which has attained an alcohol content of perhaps 7 to 8 per cent is ready for distillation. Pumps once more serve as the means of handling the materials, this time to the series of stills, where distillation is performed by aid of low pressure steam at an average temperature of 215 degrees Fahr. Continuous distillation is a feature of the modern alcohol plant, the product passing normally through a series of distilling units, the final of which is the rectifier, where absolute purification and deodorizing is accomplished.

In the process of distillation no difficulty is experienced in bringing about complete removal of any oil which has been previously used to reduce the foam in the fermentation tanks, due to the comparatively low boiling point of the alcohol and the fact that still temperatures are considerably below the boiling points of the types of oil used.

Final handling is also by pumps, this time from the still house to the storage tanks or denaturing plant where denaturants under a wide variety of formulae may be added according to the ultimate purpose for which the finished product is to be used.

Alcohol for medicinal or beverage purposes, or for blending with cosmetics, perfumes or extracts, is marketed as "cologne spirits" absolutely free from fusel oils or aldehydes, which would otherwise affect the taste and odor.

The process of distillation is very much the same, whether alcohol is to be manufactured for industrial or beverage purposes, with the exception that but one still may only be used, in the whiskey distillery.

GRAIN HANDLING METHODS

Handling of grains in the distillery may be a manual operation where grain is received in bags, or an extension of the methods of handling employed in the grain elevator, where bulk delivery prevails. The latter is widely practiced in larger distilleries. In the average distillery, however, volume is not as great, nor is it essential to have such extensive conveyor systems as in the elevator. Furthermore, the violent agitation to which the grain is generally subjected in prior handling to and from the elevator will effectually remove the greater part of the dust, with the result that explosion hazards from dust accumulations will be markedly reduced. For this reason the distillery can dispense with the normally elaborate systems for dust prevention, which are so necessary in the elevator.

This freedom from excessive dust is conducive to better lubrication. It also affords more latitude in selection of bearing and gear housings, for dust-tight construction is not so absolutely necessary. A certain amount of cleaning of grain, however, is always essential This is normally done in the receiving separator, wherein the grain is passed over a magnet to remove any iron, and then over a combination of screen cleaners and air screens. The former remove any large particles of foreign matter. Air screens, in turn, remove any final traces of dust or broken particles of grain; at the same time a sizing operation is performed.

Conveyors are confined chiefly to the belt, screw or bucket type. They are rugged in construction to withstand hard usage, and of comparatively simple design. From a lubrica-

tion viewpoint, their requirements apply to the bearings which support the conveying medium, and the gears or chains of the driving mechanism. All of these various types of conveyors are readily capable of handling considerable volumes of dry materials. For one level handling the screw or belt conveyor is adaptable, although the latter can be set on an incline where slight elevation of product is necessary. Normally this incline should not exceed eighteen to twenty degrees.

The screw conveyor operates in a trough, the screw or spiral moving the grain along the latter by virtue of its rotation. Lubricated parts in such a conveyor include the hanger bearings at the end, which are usually mounted as an integral part of the trough, and the driving element which is usually a set of speed reduction gears. To assure of most satisfactory operation the latter should be covered by a steel or sheet metal housing which will prevent loss, splashing or contamination of lubricant.

In contrast with the screw conveyor, the belt type involves a considerably greater number of bearings, with less opportunity for protection unless specially designed housings are used, due to the extent to which the grain is exposed. Modern conveyor belt construction provides for sets of carrying idlers over which the belt travels. Each set consists of a trough idler, set at an angle at each side, with a companion horizontal idler in the center to support the centre of the belt. This idler construction allows the carrying surface of the belt to form a trough, thereby facilitating the handling of substantial loads without spilling. The empty or returning part of the belt, however, is usually carried on straight idlers.

The bucket conveyor is best adapted to elevating or raising grain from one level to another, although it is perfectly practicable to design it for horizontal operation. In construction it consists of a parallel pair of chains or articulated rods, or in some cases a belt, which serves to carry the buckets or scoops. Lubrication is chiefly confined to the bearings of the traveling element.

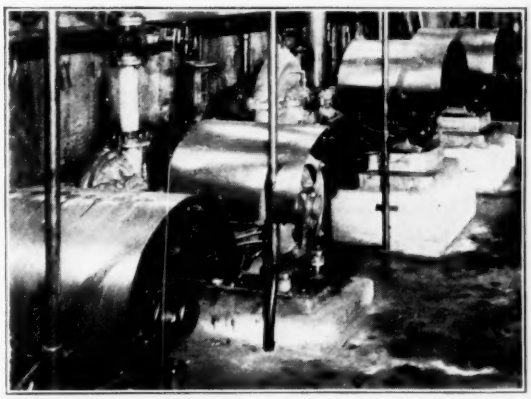
Grinding Operations

The mashing process as practiced in the preparation of grain for fermentation, is accomplished by grinding in order thoroughly to disintegrate the grain kernels. It is frequently brought about by the use of grinding rolls similar to those employed in the flour mill. These rolls must be accurately constructed and carefully adjusted for they must be exactly parallel, so that the grain in passing through them will be subjected to the same clearance and pressure along the entire length of the rolls. Where heavy crushing is essential it may be advisable to taper the ends of the rolls slightly, to prevent them from coming in contact at these points, should expansion, due to the heat generation, develop during operation.

Rolls are normally operated by belt connections on the drive side of the machine. It is practicable, however, to use either belts, chains or gears on the slow side. The main drive is connected to a line shaft pulley or electric motor. In such mills one roll normally travels faster than the other. The relative speed ratio is controlled by the size of pulleys used.

Lubrication of the roll bearings may sometimes involve a problem due to the comparatively high speeds and pressures developed during operation. To assure of positive lubrication, the plain sleeve type bearing, equipped with a fixed collar type of oiler has been widely used in the past. More recent installations, however, have adopted the anti-friction bearing to some extent. The former provides for automatic circulation of oil at a uniform rate all the time the machine is operating. The ball or roller bearing, on the other hand, is normally a unit-lubricated device, being frequently designed for grease lubrication by means of a pressure gun.

The fixed collar type of bearing has a distinct advantage due to the ability of the collar to restrict the lateral motion of the roll. To prevent damage to rolls should any hard, foreign substance be fed in with the grain, one roll is usually held in position by coil springs,



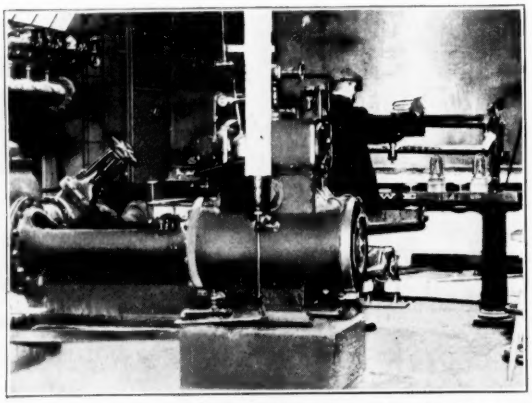
Courtesy of U. S. Industrial Alcohol Company

Fig. 2—Showing a battery of molasses mash centrifugal pumps and their respective driving motors.

which are adjustable to enable control of normal clearances and crushing pressures. These latter may be as high as 4,000 pounds, according to the type of grain being handled. Speeds will range in the neighborhood of 500 revolutions per minute.

In view of the heat generated during the

grinding process, and the possibility of its transmission to the bearings, study of operating temperatures should be made in order to select lubricants which will have adequate body at these temperatures, to render the resultant lubricating film capable of resisting being squeezed out from the bearing clearances under the prevailing pressures.



Courtesy of U. S. Industrial Alcohol Company
Fig. 3—Reciprocating steam pump used for handling of alcohol.

PUMPS—CYLINDER AND BEARING LUBRICATION

The trend toward continuous distillation in modern plant operation has developed a need for pumping equipment capable of positive service at widely varying loads. For this reason, pumps require careful consideration, especially as to lubrication, since their ability to function dependably is largely contingent upon the protection afforded by the lubricant employed.

Steam driven reciprocating pumps and centrifugal pumps driven by electric motors are largely used in this service. Lubrication must, therefore, be studied from two angles:

(1) as it may pertain to steam cylinders and reciprocating parts, and
(2) to bearings of the sleeve or anti-friction type.

Consideration of steam cylinder requirements will serve a double purpose, for it will apply to engine and boiler room equipment as well as to the pumps located in the distillery department.

Oil Contamination of Exhaust Steam

In view of the fact that oil is used to reduce the foam forming tendencies in the process of fermentation, it is not necessary to worry about oil being carried over to these vats by exhaust steam, where the latter may be used for heating purposes. Later on, however, during the process of steam distillation, oil may become a problem, but even here it will normally be of little concern, due to the wide margin by which the boiling points of virtually any petroleum product adaptable to distillery service, exceeds the boiling point of alcohol or whiskey.

And yet, it is just as well to guard against the oil content of exhaust steam in the distillery from becoming too high, for the latter can only be indicative of over-lubrication and therefore it can be taken as a warning of extravagance or carelessness in application to steam cylinders or pumps in the power plant. The steam turbine or turbo-driven pump, of course, eliminates this possibility of oil contamination of exhaust steam, because there is no necessity for lubrication of the mechanisms actuated by the steam. Such equipment may, therefore, be regarded as possessing more or less of an advantage from this point of view.

Effect on Boiler Feed Water

Wherever exhaust steam may be used as make-up or for pre-heating of boiler feed water by direct injection, presence of oil must be given serious consideration. Oil in the form of fine emulsions in a boiler combines with the boiler compounds to cause foaming, or reacts with the boiler water impurities to produce a coating over the tubes and fire surfaces. This coating seems to form more readily over relatively clean tubes than over dirty ones.

A very thin layer of oily sludge over a tube surface will so insulate it that there is not only a large loss in heat efficiency, but also the rise in temperature of the metal may be so excessive as to cause burning out or explosion of the boiler tubes.

Selection of Steam Cylinder Oils

In view of the foregoing, it is obviously important to study those factors in steam cylinder lubrication which may foster retention of oil by the exhaust.

As a general rule, it is felt that these will involve the rate of oil feed, the type of equipment, and the amount of compound used. The former can, of course, be controlled by the operator; in an existing plant, however, the type of engine, pump or compressor is fixed. Compounding in turn is a refinery process; plant operators, on the other hand, by judicious study of cylinder oil characteristics, can obtain such products with varied amounts of a number of fixed oil compounds, according to their operating requirements. The use to which the exhaust steam is to be put is of decided importance in connection with these latter.

The purpose of compounding is to improve the adhesiveness of steam cylinder lubricants. It is, therefore, a function of the moisture

content of the steam. From the viewpoint of actual composition of a cylinder oil, the question of moisture in the steam is the most important factor involved.

Steam will always contain a certain percentage of moisture unless it is superheated to a sufficient extent to counteract any line and cylinder condensation which may be caused by the cooling effect of the piping or cylinder walls, and the expenditure of heat by the expansion stroke. The presence of moisture in steam will usually result in a film of straight mineral lubricating oil being rapidly washed off from the cylinder walls and other surfaces with which the steam comes in contact. Therefore, to secure proper lubrication under wet steam conditions it is necessary to increase the rate of flow of the straight mineral oil, or substitute an oil which contains a certain percentage of fatty compound such as lard oil, degras (wool fat) or tallow.

The use of a straight mineral oil to lubricate wet steam is customary only where the presence of a fatty oil in the exhaust steam is objectionable.

Compounding Aids in Emulsification

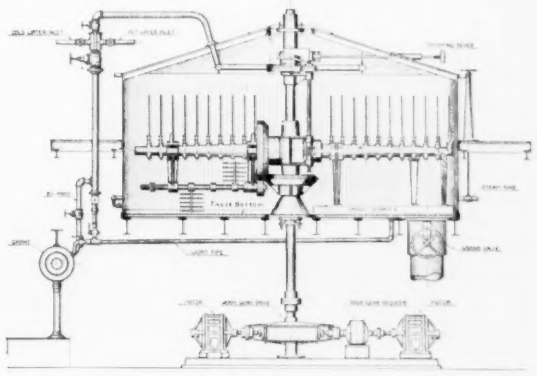
Where a compounded oil is used an emulsion is developed by the moisture in the steam reacting with the fatty component. The lubricating film thus has a greater affinity for the cylinder walls and other wearing surfaces and becomes highly resistant to the washing action of the water in the steam. Naturally the greater the percentage of moisture in the steam the higher should be the fatty compound content of the lubricant. In general, the compound should not exceed 10 per cent however, except in extreme cases of abnormally wet steam. It should be remembered that an excessive amount of fatty compound, beyond that necessary to form the requisite emulsion, will not improve the lubricating value of the oil. In fact, it may even be an objection, especially under continued exposure to high temperatures, on account of the tendency that animal fats have to decompose under such conditions.

Amount of Compounding

In regard to the proper amount of compound to use in an oil, it can be said that this should be just sufficient to maintain a film of oil on the cylinder walls. This is especially true where the exhaust steam is to be used for feedwater heating or in process work of any nature. Under such conditions it is more important than ever to observe caution in selecting and using steam cylinder lubricants.

Present day practice is more and more to reduce the quantity of compound and to improve its quality.

That tendency in compounded oils which causes them to unite with water to form emulsions in the cylinders also prevents ready separation from water in condensed steam; furthermore, the more completely atomized



Courtesy of Atlas Copper and Brass Manufacturing Company

Fig. 4—Sectional view of a mash tank adaptable to preliminary handling of grain products, showing relation of working parts. Lubrication is confined to the driving element a comparatively heavy oil being used.

the oil, the more difficulty will it have in separating from water.

In this respect, it also is of interest to note that compounding improves the atomizing ability of the average cylinder stock. For this reason it must be confined within the lowest possible limits where exhaust steam is to be used for open feed water or process heating purposes.

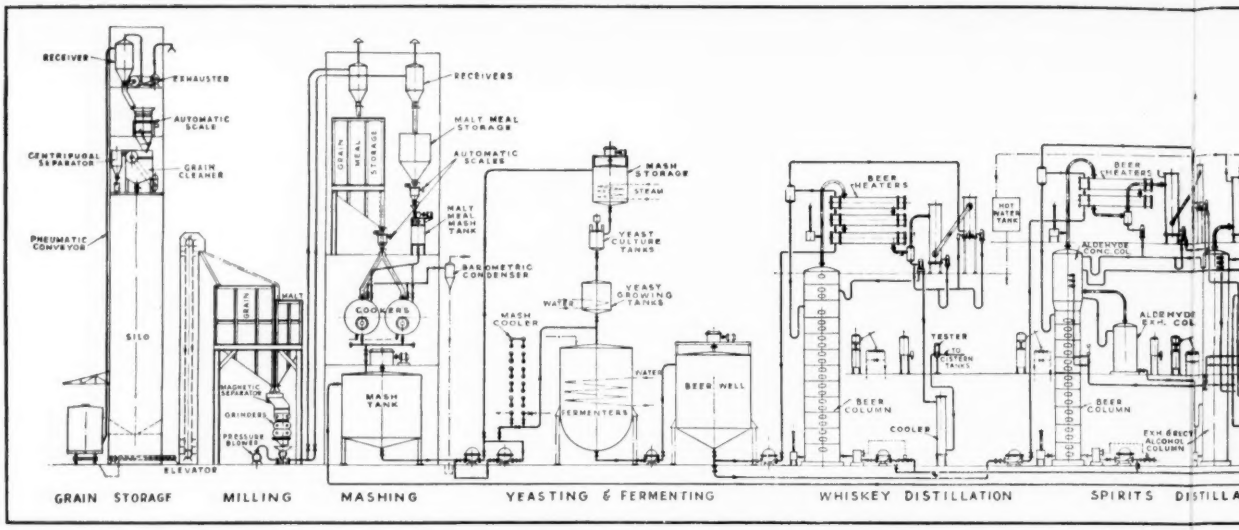
Lubrication of External Parts

Plain babbitted bearings will predominate for the carrying of external reciprocating parts on steam pumps. Their lubrication is taken care of either by means of oil or grease according to the lubricating devices installed. Where oil is required a medium viscosity straight mineral product of from 200 to 300 seconds Saybolt at 100 degrees Fahr., should be used. For grease lubrication a medium consistency cup grease will be best in the type of compression grease cups which are used on such mechanisms.

CENTRIFUGAL PUMPS

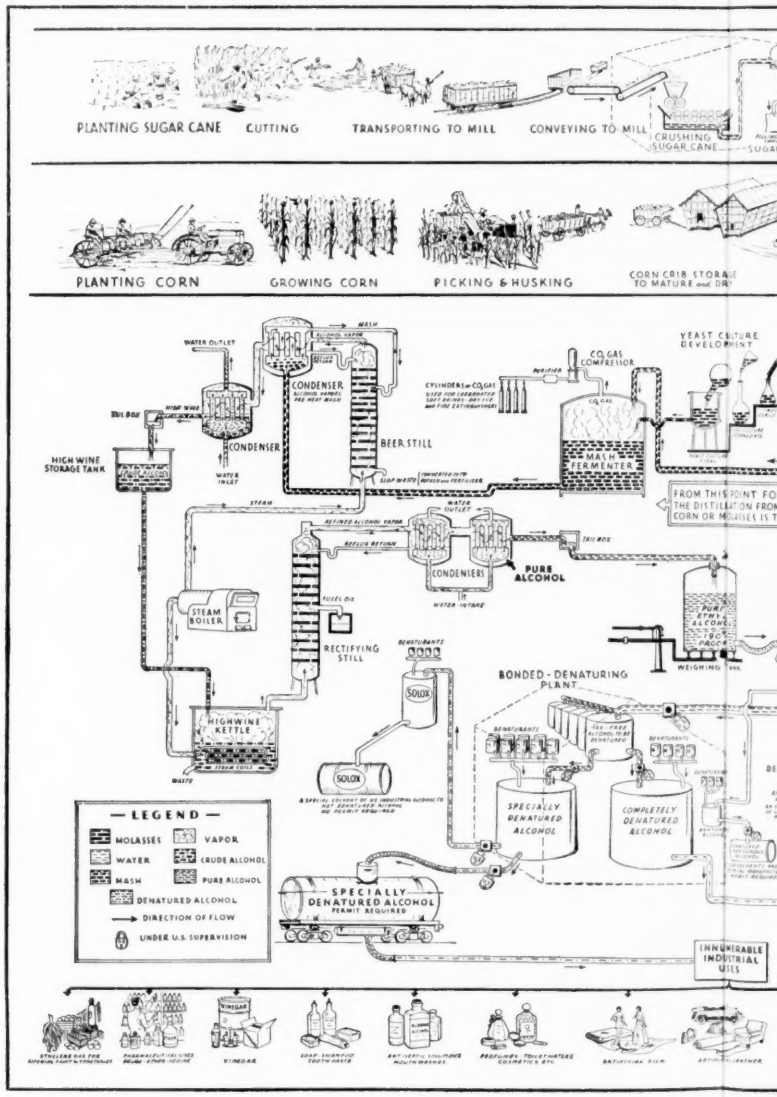
The centrifugal pump is also very suitable to the handling of distillery products. It is a pistonless type of construction, designed to transfer fluids by means of rotary motion. There are no internal parts requiring lubrication, and no valves, springs, or other small parts to wear out and become inoperative.

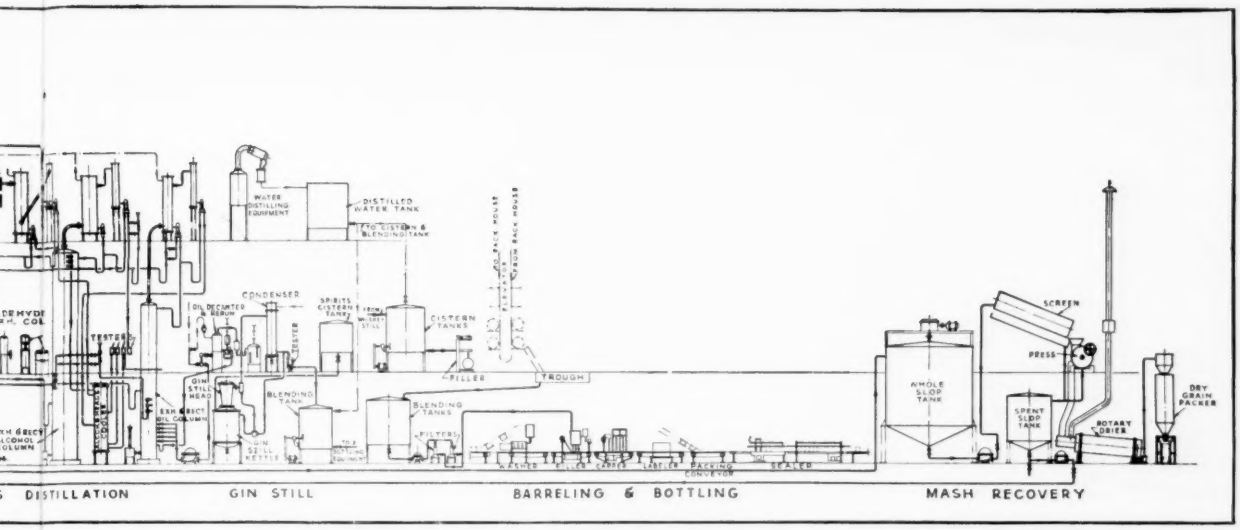
Pumps of this type involve one or more impellers, revolving in a fixed plane within a suitable air tight casing. The liquid enters at the hub or centre of the impeller, pressure

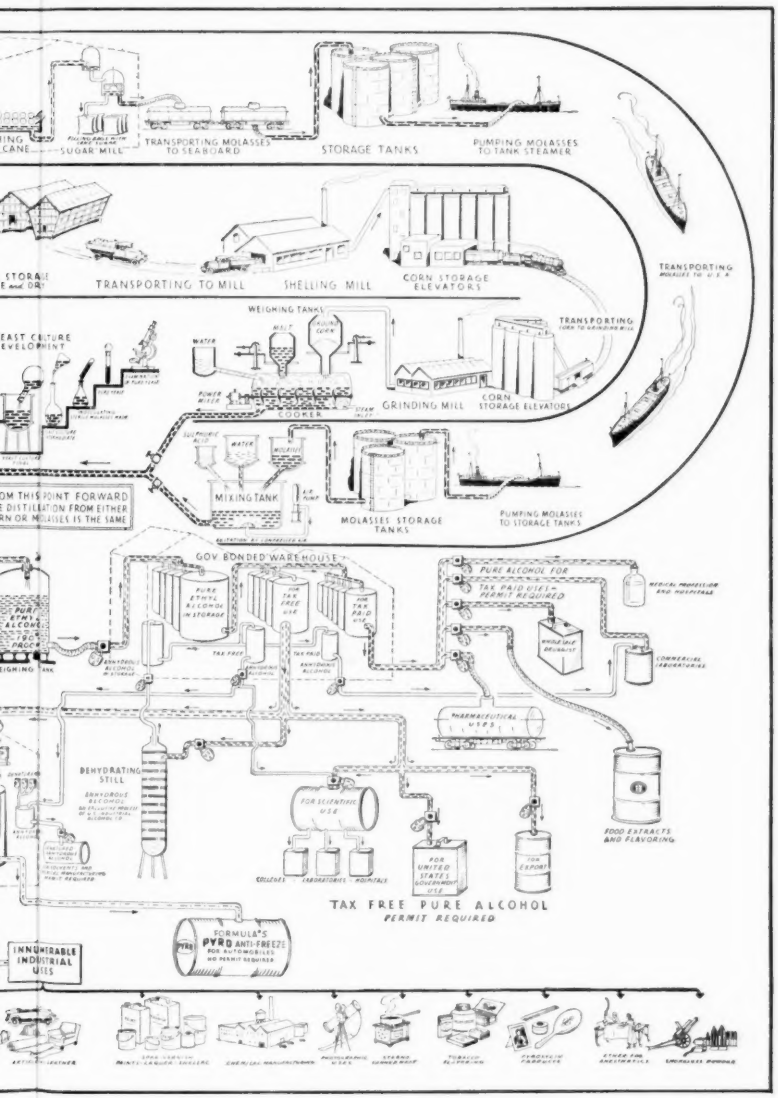


Courtesy of E. B Badger and Sons Company

Fig. 4 (*Above*)—Flow chart of a modern distillery, showing various stages of operation and types of machinery employed in the transition of grains to alcoholic products.







Courtesy of U. S. Industrial Alcohol Co.

Fig. 5 (*Left*)—Important stages in the manufacture and distribution of industrial Ethyl alcohol from the raw materials to its myriad uses in industry.

being acquired as it is impelled outward to the circumference, by means of suitable blades. Fixed discharge valves similar to stationary nozzles may be used, or a suitably designed spiral casing may be employed.

Any centrifugal pump must function free from air leaks, not only in the suction, but also in the pump; the discharge pipe must be of such a diameter as to insure the delivery of the liquid with a minimum of friction; the operating speed must be commensurate with the pumping head, and there should be a minimum of sharp bends and elbows in any piping involved. Under such conditions maximum efficiency should result.

Lubrication Requirements and Bearing Design

The bearings which carry the rotating elements are the only parts of a centrifugal pump which require lubrication. They may vary in design and involve specific problems according to the operating conditions and the viscosity or acidity of the fluids being pumped. As a result, they require serious consideration and can not be regarded simply as another case of ring oilers, ball bearings, or plain babbitted bearings served by oil or grease cups, for any failure might seriously disrupt production.

For general all-around service on horizontal pumps the ring oiler is preferred by many builders, due to its comparative simplicity, cleanliness, the extent to which it brings about automatic lubrication, the small amount of attention which it requires, its economy, and the uniformity and regularity of oil distribution. In construction, the ring oiler comprises a bearing housing which is built with a reservoir and a slot of sufficient width and depth to permit one or more rings suspended from the shaft to revolve therein. With the turning of this latter, these rings are rotated. This enables them to carry a certain amount of oil to the top of the shaft, from whence it is able to flow into the bearing oil grooves and clearance space, to be ultimately distributed to the entire wearing surface. As a rule, the oil, after being passed through the bearing, will flow out to the end or ends of the shaft through a suitable return chamber which is part of the bearing housing, back to the oil reservoir below.

Ring oiling brings about flood lubrication of bearings with a considerable excess of oil over the amount that would theoretically be necessary to furnish the requisite oil film. In bearings designed for flood lubrication the oil serves not only as a lubricant, but also as a cooling medium to carry away part of the frictional heat developed, thereby reducing the temperature of operation. If the oil reservoir in the base of the bearing has been properly designed and is of sufficient capacity, this overheated oil will have ample opportunity to become sufficiently cooled after each circulation by contact with the reservoir walls, particularly if thorough radiation can be maintained.

Lubricating systems of this type possess natural advantages in that the flood of oil which is constantly passing through the bearings tends to wash out any grit, dirt, dust or metallic particles that may have gained entry, as a result, reducing wear to a minimum. On account of this washing action of the oil, however, the reservoir will gradually tend to accumulate a certain amount of sedimentary deposits. Therefore, it should be flushed out and the oil changed at regular intervals. This is especially important when such a system is new and core sand, etc., may be present.

Flood lubrication works on the opposite theory to that of supplying a bearing with just sufficient oil to furnish the necessary lubricating film. In fact, today in many types of machinery, flood lubrication is the only method considered by the builder. On the other hand, there are many arguments in favor of regulated lubrication, such as embodied by the drip cup or automatic force-feed lubricator, especially where bearings cannot be built oil-tight, or where a certain amount of pressure on the lubricant is desirable.

Wherever ball or roller bearings are used to replace the sleeve type of bearing, sliding motion is replaced almost entirely with rolling motion, thereby reducing the resultant friction where properly lubricated. Ball bearings involve theoretical point contact, whereas roller bearing involve line contact. In the lubrication of either type one of the chief functions of the lubricant is to prevent corrosion of the highly polished surfaces. As a result, wherever possible, the housing should be effectively sealed, for thereby can the body of the lubricant be reduced and likewise the probable internal friction that will be developed during operation.

In bearings which are oil-tight a comparatively light bodied straight mineral oil is usually adaptable, unless abnormally high temperatures may prevail. Under such conditions a heavier oil or a grade of grease should be used which will have just enough body to cause it to remain in the bearing housing. Lubricating attachments may or may not be used on such bearings; irrespective of their use, however, it is necessary to charge or fill the housings and raceways periodically with the proper grade of lubricant, through a suit-

able orifice or fitting which can be effectively sealed or plugged during subsequent operation to prevent the lubricant from flowing out. In general, one charge of oil to a roller or ball bearing equipped with an oil-tight housing should last for a period of several months. Where grease is required, however, it should be renewed according to the extent of the seal which is maintained. Effort in modern design of such bearings is to lengthen the period between lubricant applications as far as possible.

EFFECT OF ACIDS ON PUMP LUBRICATION

In the process of fermentation, acetic acid, is often developed. More or less sulfuric acid may also be carried over from the mashing operation. Weak sulfuric acid may be particularly corrosive to some types of steel. Both acids are also felt to be detrimental to lubricated pump packing. For these reasons selection of pump lubricants wherever packing or antifriction bearings require protection, may present somewhat of a problem. It is the opinion of some lubrication engineers that where the lubricant can be applied under a certain amount of constant pressure, more positive maintenance of a uniform film will be assured over the bearing and shaft surfaces. This will call for continual renewal of the lubricant supply, but the benefits which will accrue in the form of increased life of packing and bearings will justify serious consideration of such a method of lubrication.

EFFECT OF MOISTURE ON LUBRICATION

Maintenance of lubrication in certain parts of the distillery must be carried out in the presence of more or less moisture. This may become a decided detriment if the lubricants employed are not capable of resisting the washing off effects of water. The petroleum industry has carried on extensive research for the purpose of developing both oils and greases of high moisture-resisting properties, in order to insure dependable formation and maintenance of protective lubrication, irrespective of pressures, temperatures, or presence of water or other fluids. The essential characteristics must, of course, be understood by the operating engineer if he is to choose such products intelligently, and with assurance that they will meet his operating conditions.

The necessity for a water-resisting oil was first demonstrated by steam cylinder operations where steam carrying a considerable amount of water was to be used. Here it was found that a considerable washing action on cylinder walls was developed by this water content, to result in frequent impairment or complete removal of the oil film. To overcome this tendency it was found that the adhesiveness of the lubricating film could be markedly increased by addition of a certain amount of animal oil such as tallow or wool oil. Since this earlier work, research has been extended to study of the relative emulsifying tendencies of various other types of fixed oils of both animal and vegetable origin, also the water solubility of the various types of soaps used in grease manufacture. Further discussion should be of interest to the distillery operator, especially since he must select both oils and greases for a more or less wide variety of mash tank, pump and conveyor bearing service.

The extent to which any grease will successfully resist breakdown of its lubricating film in the presence of moisture will depend on the relative solubility of its soap content. Obviously this latter must be non-soluble, otherwise its ability to function as a carrier for oil would be impaired in the presence of water. Soaps of a lime or calcium base are most insoluble in water. They have, therefore, been largely favored in the compounding of greases for use in the presence of moisture. A field for such products in the distillery would be the lubrication of bearings of centrifugal pumps, used for transfering the contents of fermentation tanks to the distilling equipment.

Soda soaps, on the other hand, are relatively soluble in water. Consequently, when used where they may come in contact with moisture, the soap content might be dissolved, to leave an oil which might oftentimes be incapable of maintaining lubrication or remaining within the bearing or clearance space due to ineffectual closure. The washing action of any water or other fluids would aid in this removal of the lubricant from the contact surfaces.

Where greases are specifically prepared for service in the presence of moisture, practice is frequently to use oils of low pour test and comparatively low viscosity, in order to insure against abnormal resistance to flow or handling where low temperatures may be encountered.

Compounding of mineral oils, in turn, where provision is made for oil lubrication, leads to development of a permanent emulsion which is very tenacious to metals. Emulsions can also be developed by agitating straight mineral oils with an excess of water, but unless the oil has been under-refined, the resultant emulsion will be temporary and unstable. One can, therefore not rely on a straight mineral oil to maintain effective lubrication in the presence of an appreciable amount of water. In distillery operations the field for compounded oils is largely confined to pump and engine room operations, for the lubrication of steam cylinders of various external bearings.

Emulsification, Demulsibility, and Methods of Test

The necessity for pre-determined knowledge of the manner in which certain types of lubricating oils will behave in the presence of water, and those characteristics which will be indicative of ready separation, has called for extensive study of the phenomenon of emulsification and its counterpart—demulsibility.

Emulsification is of distinct importance in certain types of operation where lubricants must function in the presence of water, which will require formation of a lubricating film of greater tenacity than can normally be obtained from a straight mineral oil.

The demulsibility in turn should be thoroughly investigated where rapid separation from water must occur in operation, for example, as in connection with steam turbine lubrication.

In general, emulsification is developed by compounding with a fixed oil. What actually occurs in operation can best be understood by assuming that a well refined mineral oil is shaken up with water in a bottle, and then allowed to stand and settle for a few seconds. It will be noted that the respective liquids will separate, with a sharp surface of demarcation and that each will be comparatively clear. If, however, certain fixed oils or soaps are added to the mineral oil and the subsequent compound similarly agitated with water the two liquids will separate more slowly, or they may remain mixed for an indefinite period. This intimate mixture of oil, or an oil compound with water, is termed an emulsion.

The chemist defines it as a very intimate mixture of two liquids which are insoluble or only slightly soluble in each other, the mixture being so stable and the liquids so mutually held in suspension that separation due to differences in specific gravity or density is very slow. While this definition covers the usual conception of emulsification in the oil industry, it is somewhat broader than will be used in scientific discussion.

When one considers that there are practically no limiting conditions which will definitely determine whether or not we have a complete emulsion, as the transition from a solution to an emulsion is not sharp, it can be realized that we may have an emulsion and yet the combination of the two liquids may appear clear and apparently be a true solution.

Influence upon Lubrication

Whether or not an emulsion will be essential to effective lubrication will depend upon the nature of the service, as already indicated. As stated, under water conditions it will be necessary; elsewhere, however, it must be guarded against. This will hold true especially in connection with steam turbine lubrication, where it will be of vital importance in view of the fact that wherever oxidation and emulsification may prevail to any extent, impaired lubrication may result. In fact, oxidation is in general the forerunner of sludge formation and emulsification, which may lead to oil-ways and other parts of the lubricating system becoming clogged.

Sludge, in particular, must be given careful consideration. Today it is understood as comprising those insoluble or readily oxidized components in petroleum lubricants which are thrown down in the form of gummy accumulations. It is not necessarily the result of water contamination.

Emulsibility is determined in the laboratory by simulating the extent to which agitation of a lubricant may occur in actual operation, and then noting the readiness with which separation of the resultant oil-water emulsion will occur. The object, of course, is to study the emulsifying tendency of the oil. There is, therefore, a distinct relation between emulsibility, or the rate at which an emulsion will develop when an oil is agitated with water, and demulsibility, or the rate at which this emulsion will subsequently precipitate itself or settle out.

Wherever water may gain entry into a turbine lubricating system the possibility of emulsification and the subsequent demulsibility must be given the most careful attention, not only when making initial selection and purchase of a lubricating oil, but also in its subsequent usage.

Degree of Refinement a Factor

Demulsibility, or the rate at which an emulsion will separate, and the completeness of this separation, will depend upon the degree and manner of refinement. The rate of demulsibility will often be indicative of sludge forming tendencies, though not necessarily so. In fact, with new oils showing the same demulsibility, frequently practical tests will indicate quite a difference in demulsibility after the oils have been used for some time.

It is well to remember that with heavier or more viscous oils, water and sludge will settle out more slowly than from more fluid products or those of lighter body, particularly with oils of the same degree of refinement. This is one reason why a turbine oil should be of com-

paratively low viscosity, commensurate with other conditions, such as the operating temperature of the bearings, the speed, the load, the gallonage capacity of the lubricating system, the period of rest and the means provided for separation of non-lubricating foreign matter. Furthermore, with lower viscosity oils, the operating temperature will be lower and the tendency toward oxidation reduced.

Methods of Test for Emulsion and Demulsibility

The method of determining the relative emulsifying tendencies of lubricating oils at 130 degrees Fahr., as outlined in Bureau of Mines Technical Paper 323-B* will be of interest, viz.:

Apparatus

1. A 100 c.c. graduated cylinder, $1\frac{1}{16}$ to $1\frac{1}{8}$ inches inside diameter.
2. An oil or water bath for maintaining the contents of the cylinder at the specified temperature. The line of the bath liquid shall not be lower than the 85 c.c. mark on the graduated cylinder.
3. A paddle consisting of a copper plate $4\frac{3}{4}$ inches long, between $\frac{3}{4}$ and $\frac{7}{8}$ inch wide, and $\frac{1}{16}$ inch thick.
4. Means for revolving this paddle about a vertical axis parallel to and midway between its two longer edges and for keeping the speed fairly constant at 1,500 r.p.m.
5. A stop so arranged that when the paddle is lowered into the cylinder the distance from the bottom of the paddle to the bottom of the cylinder will be about one-fourth inch.

Procedure

6. Place 40 c.c. of the emulsifying liquid in the 100 c.c. graduated cylinder and add 40 c.c. of the oil to be tested.
7. Heat the cylinder by means of the bath to 130 degrees Fahr.
8. Stir by rotating the paddle for five minutes at a speed of 1,500 r.p.m., stop the paddle, withdraw from the cylinder and wipe clean, returning to the cylinder as much of the emulsion as possible.
9. Allow the cylinder to stand at 130 degrees Fahr., for the specified time, and then inspect. No continuous layer of emulsion shall remain.

In addition, there is the demulsibility test † which employs the same apparatus as above, but which uses different quantities of oil and measures the maximum rate of separation instead of the time.

Another test which is being given considerable study today is the steam emulsion test, as developed and adopted by the American Society for Testing Materials. In practice it involves passing live steam into a measured quantity (twenty milliliters) of oil, under controlled temperature conditions of from 190 to 195 degrees Fahr., for a specified length of time, i.e., 4 to 6.5 minutes. The oil container is then transferred to a separating bath where the surrounding temperature conditions can be kept within a range of from 200 to 203 degrees Fahr. The volume of the separated oil layer from condensed steam is observed periodically at not less than 30 second intervals, until 20 milliliters have separated. The elapsed time in seconds from withdrawal of the steam delivery tube until the above amount of separation has occurred is taken as the steam emulsion (S. E.) number.

According to the Society‡ in discussion of the significance of the results of this test:

"For forced-feed circulating lubrication systems where the oil is likely to come in contact with water or steam, the steam emulsion test is of great importance. This is particularly true of steam-turbine lubricating systems. For oils intended for this type of service the use of a test of this kind is thoroughly established. Next to viscosity it is considered the most important test for steam turbine oils, since rapid separation from water is an essential characteristic."

Effect of Oxidation

Among the factors which may influence the demulsibility of an oil, oxidation is today regarded as probably requiring the most consideration. All mineral oils will be subjected to more or less oxidation when agitated with water under higher temperatures in the presence of air. In other words, oxidation will occur in practically any oil if it is subjected to oxidizing conditions. In fact, wherever particles of air and water are suspended or retained within the body of an oil to form an emulsion, in some cases only a slight elevation of temperature during circulating or agitation may be necessary to bring about an oxidizing reaction between the air and oil.

These conditions are normally so involved and so contingent upon one another that no one of them can be rightly claimed as being more detrimental than the other. On the whole, however, it may be stated that the extent to which oxidation will occur depends largely upon the refinement of the original oil.

* Method 320.11—Emulsion test at 130 degrees Fahr., p. 84

† Method 320.31 Technical Paper 323B U. S. Bureau of Mines, p. 85 Demulsibility at 130 degrees Fahr.

‡ Significance of Tests of Petroleum Products, A.S.T.M., p. 38

In other words, certain petroleum hydrocarbons will probably oxidize more readily than others. Logically, it would be advisable to bend every effort in the refinery to effect the removal of these components by careful refining. The more reliable the manufacturer, naturally the more dependence can be placed on his methods of refining.

Metallic Particles Must Also be Considered

Oxidation, furthermore, is accelerated by the effect of certain metals, especially brass, bronze, and iron, or other foreign matter, such as dust and dirt. In fact, in an already emulsified oil foreign matter of this nature is regarded as being the co-partner of oxidation in producing the resultant insoluble sludges so detrimental to proper lubrication.

It is believed by some that if emulsion is prevented, sludging will be greatly lessened. But emulsion involves only oil and water. It would, therefore, seem logical to consider foreign matter, or the catalyzers such as metallic particles which promote oxidation, as an equal detriment.

Emulsions alone are certainly not so viscous, adhesive, and generally objectionable as insoluble sludges which frequently clog oil passages, congest the oiling system, and generally reduce the lubricating quality of the oil.

The natural procedure is, therefore, to reduce the effect by removing the cause as far as possible; in other words, by purifying the oil during operation to a sufficient degree to keep down the percentage of water, emulsion, and foreign matter.

The latter can also be prevented to a considerable extent by using steel piping and fittings throughout the oiling system, for steel has the least tendency to chip, corrode, or otherwise contaminate the oil with metallic particles as it passes through the lubricating system.

Sludge Formation—The Result of Oxidation

Sludge, as it may be developed when a turbine oil is agitated in the presence of air or water, especially under overheated conditions, is formed in two stages, viz.:

The colloidal or soluble stage, which is more or less of a primary development, and

The insoluble stage, wherein the sludge becomes permanent in form.

In the colloidal stage if water is present a fairly stable emulsion may be formed. On the other hand, the presence of an emulsion is not necessarily indicative of colloids. Both emulsions and colloidal sludges are relatively temporary at normal operating temperatures.

Emulsions, if uncontaminated and unoxidized, will clarify themselves and precipitate water on standing, leaving the bulk of the oil in very nearly the same condition as prior to agitation.

Colloidal sludges (or, as they may also be termed, soluble sludges), in turn, at temperatures above approximately 100 degrees Fahr., will be more readily absorbed by the oil. On the other hand, while present they may be a detriment to lubrication, due to the fact that the formation of a continuous, uniform oil film over the surface to be lubricated may be impaired.

Where breakdown in an oil has occurred, it will interfere with the separation of contaminating foreign matter. As a consequence, this latter will exercise its catalyzing effect on further oxidation in the bringing about of permanent sludges.

Where colloidal sludges have passed over to the state of insolubility, immediate steps should be taken to correct this by the removal of the heavy, adhesive, and relatively solid matter from the system, otherwise lubrication will be bound to be impaired.

The Effect of Water

The detrimental effect of water has already been mentioned in discussing oxidation, emulsification, and sludge formation. If a turbine and oiling system could be so designed as to eliminate the chances of water leakage or condensation occurring, provided the original oil was water-free, there would very probably be but little emulsion developed.

It must be assumed, however, that the presence of a certain amount of water and other impurities is a certainty. As a result, emulsions and sludges will be formed in the average turbine oiling system. Effective oil purification should bring about the removal of these before their proportion becomes dangerous. From a constructional viewpoint, therefore, a turbine oiling system should be so designed as to permit of ready separation of impurities from the oil by means of the reconditioning apparatus.

Where the oil is in a sufficient state of purity, separation from water will normally occur comparatively readily, for the emulsion caused by agitation will be of relatively temporary character.

Printed in U. S. A. by
EDGAR C. RUWE CO., INC.
72 Washington St., N. Y. C.